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ANNUAL REVIEW OF LITERATURE, 1951. I. STREAM POLLUTION. II. ANALYTICAL METHODS. III. RADIOACTIVE WASTES

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Environmental Health Center
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ANNUAL REVIEW OF LITERATURE (1951)

on

I. STREAM POLLUTION

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STREAM POLLUTION - Abatement and Control

Numerous articles dealing with the general problem of abatement and control of water pollution have appeared in the literature. Hedgepeth (76) reviewed pollution abatement activities and stated that cooperative efforts of industry, government, and others can produce a solution for the problems. Murdoch (92) discussed the problem of conflicting interests of water users and concluded that it is the responsibility of the State to exercise its powers of legislation and enforcement to protect the public health and safety. Hollis (81) briefly reviewed the history, present status, and future requirements of waste treatment and stream sanitation. The responsibilities of industry in the accomplishment of stream pollution abatement were described by Cox (67). Nord (96) stressed the need for an educational approach to the problem of stream pollution and discussed the psychology, technology, and economics of pollution abatement.

Howson et al (84) summarized the critical problem of water supply and stream pollution. The factors responsible for water shortage and the disposal of oil field brines, coal processing wastes, and mine acid were discussed. A comprehensive summary of water pollution control policy was presented. A policy for pollution abatement was also discussed by Camp (66). The capacity of streams for self purification and the contamination of ground water by industrial wastes were considered. Pugh (99) discussed ground water protection and controlled discharge of impounded flood waters and the research activities of the Institution of Water Engineers.

The Federal Government's water pollution control program and recent proposed legislation concerning pollution control were described by Pond [98]. The status of water pollution abatement in the United States and the trend toward the organization of State water pollution control agencies which include representation for all major interests were summarized by Hollis [82]. A national summary of water pollution, the first of the Water Pollution Series being produced in compliance with the Water Pollution Control Act (Public Law 845, 80th Congress), by the Public Health Service, Division of Water Pollution Control, was published [58]. Several articles discussing this report appeared in the literature [26,28,59]. The report indicated that the construction of required new or improved waste treatment facilities for some 10,000 municipal and industrial sources of pollution will require the investment of 9 billion to 12 billion dollars over the next decade. Other reports in the Public Health Service Water Pollution Series which have been released are the summary reports for the following major drainage basins: California Drainage Basins [44], Colorado Drainage Basins [45], Great Drainage Basins [46], Missouri River Drainage Basins [47], New England Drainage Basins [48], North Atlantic Drainage Basins [49], Pacific Northwest Drainage Basins [50], and Tennessee River Drainage Basin [51]. These cooperative State-Federal reports present information as of July 1950, concerning pollution being discharged to the streams of the basins, the damages resulting from this pollution, the benefits which may accrue as a result of pollution prevention and abatement, the pollution prevention measures in effect, and the pollution prevention measures required. Most of the numerous articles [1,16,30,52,101,109] which discussed these reports elaborate

on the cost and need of waste treatment facilities.

The Third Annual Report of the Ohio River Valley Water Sanitation Commission [24] reviewed the activities of this eight State Commission and described the projects undertaken, the progress made, and the pollution abatement objectives of the Commission. Of significance to all interstate commissions was a decision of the Supreme Court of the United States which verified the constitutionality of this Compact and thus reversed an opinion by the West Virginia Court of Appeals that the agreement was in violation of the West Virginia Constitution [25]. Articles dealing with activities of the Commission described the progress made in the municipal and industrial pollution abatement programs in the Ohio Basin [15,40,60].

Vermont [55] and New Hampshire [20] have joined Connecticut, Massachusetts, New York, and Rhode Island as official members of the New England Water Control Commission. The Interstate Sanitation Commission (New York, New Jersey, and Connecticut) reported on its activities for 1950 [33]. The first phase of an Interstate Sanitation Commission investigation of the industrial waste problem along the 1,500 mile Connecticut, New York and New Jersey Coastline was reported [22] that some 300 industrial plants discharge a total waste load of more than 500 m.g.d. Approximately one-fifth of the load was discharged into recreational waters. Recent progress made on the Potomac River pollution abatement program was reported [42].

Bacon [62] discussed California's pollution control legislation which defined areas of jurisdiction by State agencies. The organization of boards to apply this legislation and a tentative water quality criteria report

were described by Grayson [14]. Favorable results for the first year of operation of California's pollution control plan was reported [27]. The progress of the Water Pollution Control Board in the establishment of water quality standards for catchment areas, plains and valleys, and coastal areas was reported [32]. A method was included for the analysis of waste problems to determine waste treatment needs.

The completion of treatment plants at Bridgeport and Waterbury, Connecticut, will bring to 90 per cent the portion of Connecticut's sewage flow which is treated prior to discharge [6]. It was estimated that these facilities will decrease the pollution of the State's coastal and inland waters by more than 60 per cent.

The major points of interest in the development [17,29] and enactment [18] of the North Carolina stream sanitation law by the State legislature were reported. The law provides for an eight man Stream Sanitation Committee which is to operate under the jurisdiction of the State Board of Health. All bodies of water within the State will be classified and a permit will be required for new waste discharges. The appointment of six members of the North Carolina Stream Sanitation Committee was reported and that portion of the law which defines the powers and limitations of this Committee was discussed [19].

The Ohio Legislature enacted a new pollution control law to become operative in September 1952. The steps leading up to its passage and the provisions of the law were summarized [23]. Seven bills concerning stream classification were introduced in the New Hampshire legislature and six bills concerning a study of sewage and industrial wastes in streams of the State were introduced in the Massachusetts legislature [53].

Activity by several States concerning the fight against pollution of water supplies was reviewed (8) . This same article described the Ohio State Department of Natural Resources Survey of Lake Erie bathing beaches and reported that Pennsylvania had ordered a number of coal mine operators to suspend the discharge of acid mine waters into streams of the State. Gillewater (73) discussed the problem of coal washery wastes in West Virginia and reviewed means for abatement. The State of West Virginia is currently making a survey to determine the scope of this problem.

Thirty cities in Ohio, mostly in the Mahoning River Valley, Miami River Valley, and Lake Erie regions, have been ordered to begin activities for providing sewage treatment facilities (2) . The Virginia State Water Control Board ordered the City of Alexandria to provide treatment for its sewage discharged to the Potomac River (41) . Following the reduction of pollution of the Schuylkill River by silt and coal fines, the Sanitary Water Board of Pennsylvania ordered municipalities discharging wastes to that river to increase their degree of sewage treatment (36) . The Sanitary Water Board of Pennsylvania also acted concerning coal mine operators not complying with regulations on the discharge of acid mine wastes and initiated experiments to make the regulations more effective (5) .

The stream pollution control program of the State of Tennessee was described by Farrell (70) , that of Texas, by Smallhorst (105) , and that of Wisconsin, by Wisniewski and Muegge (111). An article by Bacon, DeMartini, and Harris (63) summarized the pollution control statutes of Arizona, California, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming as they apply to the discharge of industrial wastes.

Smith, Moody, and Leifee (105) summarized a legal study of court decisions on the use of the waters of a public stream. The trend in public opinion to demand more and more protection for the riparian owners along public streams was reflected in the decisions of the courts. The need for uniform State pollution control laws and the model pollution control act by the Public Health Service was discussed in an editorial (54). This "Suggested State Water Pollution Control Act" was prepared by the Division of Water Pollution Control, Public Health Service, and critically reviewed by experts from State pollution control agencies (43). The Council of State Governments endorsed the suggested act and recommended it to the States for their favorable consideration.

The history of Federal anti-pollution legislation, from the protection of navigation in 1886 to the comprehensive pollution control legislation of 1948, was reviewed by Murdoch (93). Babbitt (61) reported that the administration of stream pollution prevention programs was in a state of flux throughout the country at the present time. Recent and contemplated changes in legislation concerning control programs have prevented stabilization of administrative practices in many States.

The text of the law, enacted in March 1950, for the prevention of water pollution in Belgium was reported (12).

Progress in the abatement of pollution of Puget Sound (56), in the sewage disposal program in Allegheny County, Pennsylvania (14), and in the construction of sewerage and treatment facilities for Covington, Kentucky, and surrounding communities (7) (Northern Kentucky Sanitation District No. 1) was reported. Progress on the silt removal project on the Schuylkill River, Pennsylvania, on the pollution abatement program for the upper

Wisconsin River, Wisconsin, and on the construction of sewage projects in Illinois were reviewed (3).

Hammann (75) described the procedure and equipment used in the interim disinfection through chlorination of mixed domestic and industrial wastes being discharged while new treatment facilities are being constructed for the Blackstone Valley Sewer District in Rhode Island.

A steady decrease during the past 20 years in the turbidity of the Chattahoochee River waters above the water supply intake for the City of Atlanta, Georgia, was reported (9). This improvement is credited to better land use practices in the watershed area.

The need for efficient operation of sewage treatment plants which discharge effluents into surface waters was emphasized by Heuvelen (79).

Sewage plant effluent from 42 California cities and towns is now being used as irrigation water (21). Plans are also being formulated for the use of activated sludge effluent as industrial water and for the recharging of ground water strata.

The report by the International Joint Commission on the pollution of boundary waters has been approved by the Governments of the United States and Canada. Certain of the recommendations contained in the report and a cost breakdown for the 127 million dollars abatement program were reported (4).

Four task groups of the National Technical Task Committee on Industrial Wastes reported definite progress toward the more effective control of wastes (10,31). The four groups reporting represented food industries, mineral products industries, chemical process industries and general industries.

Some of the important topics discussed at the Sixth Annual Industrial Waste Conference at Purdue University were reviewed (13). One suggestion offered at this meeting was that those responsible for pollution should help finance pollution abatement research by means of fees for permits to discharge wastes.

The decreasing adequacy of water supplies and the increasing amounts of wastes have led to more critical evaluations of industrial effluents. One article listed a number of examples of successful recovery of by-products from wastes (57). The activity has resulted in the conservation of water, a decrease in pollution, and less economic loss.

The general problem of controlling the pollution of streams by industrial wastes was discussed by Steel (107) with reference to the work of the Public Health Service. Physical, chemical, and biological pollution by industrial wastes and methods of waste treatment were discussed in a number of articles (102,97,71). Miller (89) described the problems in waste disposal brought about by the wide dispersal of industry in Indiana. The general problem of stream pollution by the textile industry in New England and the satisfactory application of trickling filters to these wastes were discussed by McCarthy (87). Hedgepeth (77) emphasized that no set of rules is universally applicable to control the pollution of streams by an industrial waste.

The relationship between air pollution and water pollution was discussed (106,112,100). It was pointed out that the economical control of some types of air pollution was not now possible and much research was needed in the field.

The importance of adapting treatment and disposal of industrial wastes to the capacities of the surface streams into which they are being discharged was stressed by Mohlman (90). Some of the methods used for the treatment of trade wastes were considered. Jacobs (85) suggested that consideration of the receiving stream may indicate that it has adequate capacity to assimilate an anticipated waste load without adverse effects. Only sufficient treatment to permit the stream to meet the requisites set for it should be provided.

Hedgepeth (78) discussed the perplexing problem of wastes which do not respond to known treatment. The four fundamental concepts which must be considered in pollution prevention are: (a) proper plant location, (b) manufacturing process selection, (c) manufacturing process control, and (d) treatment of effluents to make them safe for stream assimilation.

The effects on streams and sewage treatment plants of waste fibre from paper mills was discussed by Nemeron (95). It was stated that fibre losses at some plants may be as great as 25 per cent.

Two pulp mills were ordered to discontinue waste disposal practices leading to the pollution of Puget Sound. An interim agreement with the Washington State Pollution Control Commission provided a pipeline for the discharge of the mill wastes at a point in the Sound 300 feet deep and 4,000 feet offshore (11,39).

The problem of stream pollution as it affects the tanning and leather industry was discussed by Thorstensen (108). The effects of tannery effluents on the receiving stream were described and methods for the treatment of these wastes were suggested by Bergamin (64). Vrijburg (110)

discussed the problem of disposal of waste acid and wash water from metal-pickling processes. Dougan and Bell [69] reported significant pollution reduction through treatment of wastes from a synthetic rubber plant.

Process modifications to reduce waste volumes from a large synthetic organic chemicals plant and the treatment applied to these wastes were described by Lyon [86]. McCracken [88] reported on the abatement of pollution brought about by the discharge of oxygen consuming wastes from a chemical plant. Abatement was accomplished simply through process changes. Murdock [94] reported that the elimination of obnoxious constituents from the waste of a dyeing operation improved the quality of the effluent from a textile manufacturing plant sufficiently to permit its assimilation by the receiving stream. The alleviation of a local stream pollution problem by applying the calcium hypochlorite process for the treatment of wool scouring waste was described by Cameron [65]. He reported that under optimum conditions a B.O.D. reduction of 90 per cent can be attained.

The DuPont Company's policy of providing for waste treatment facilities in all new plant construction was discussed by DeRopp [68]. Treatment facilities for all wastes are being incorporated in the construction of the company's new nylon intermediates plant in Victoria, Texas.

The British River Boards Act, 1948, was discussed by Morley [91] and by Savage [103]. Hobday and Southgate [80] discussed legal and technical aspects of some stream pollution prevention measures with reference to the powers of the River Boards. The more recent Rivers (Prevention of Pollution) Bill equips the River Boards, created by the 1948 Act, with adequate legal powers and clears the way for the rehabilitation of England's streams [35].

In contrast to the lag in the construction of waste treatment facilities in England, research in the fields of sewage and industrial wastes treatment has been active, and the revision of the Ministry of Health "Standard Methods" for analysis is being accomplished by a joint committee of interested bodies (38). Industry and government are co-operating in providing information necessary to deal with the problems of industrial effluents (37). Garner (72) reviewed the general progress in research, analytical methods, and pollution prevention for the period since 1922.

The condition of the river Ribble and its tributaries was discussed in its annual report by the Ribble Board of Conservators (34). Specific instances of pollution were cited.

The problems encountered in the discharge of wastes to the sea through submarine outfalls in Holland were discussed by Hopmans (83). Unfavorable winds and sea currents cause pollution of beaches even though outfalls are submerged at distances of 1 to 2 miles at sea. A method of calculation to determine whether wastes may be satisfactorily disposed of by discharge to estuaries was proposed.

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STREAM POLLUTION - Bacteriology

The Ohio River Valley Water Sanitation Commission (2) in April 1951 adopted bacterial quality objectives for the Ohio River. For domestic use the limit is 5000 coliforms per 100 ml. (monthly arithmetical average M.P.N.) in any month. The limit must not be exceeded in more than 20 per cent of samples examined per month nor should a count of 20,000 per 100 ml. be exceeded in more than five per cent of samples.

Results of a survey of streams and bathing beaches at Cleveland (4) in 1949 showed the pollution was substantially higher than when previously determined in 1939 to 1941. Pollution of the lake water is increasing and is derived from storm-water overflows and heavily polluted streams.

Subrahmanyan and Bhaskaran (9) have reported the results of experiments to determine the extent of pollution diffusing from bored latrines. The distance pollution travels from latrines bored into ground waters depends mainly on the velocity of ground water flow. The velocity of flow depends largely on the soil structure, but also on the gradient of the water-table. The safe distance between a borehole latrine or leaching cess pit and a ground water source may be taken as the distance represented by about eight days travel of the ground water.

The longevity of coliform organisms, Salmonella typhosa and enterococci in soil, was prolonged with an increase in organic content of the soil as found by Mailmann and Litsky (8) . Coliform organisms persisted in soil for long periods, enterococci died out rapidly and

virulent typhoid bacilli died out more rapidly than enterococci. The only organisms, other than the coliforms, found in sewage that could be used as indicators of fecal contamination were the enterococci.

Akerlindh (1) investigated the hypothesis that there was a proportionality between bacterial pollution entering a stream and the resulting bacterial density at continuous pollution. His results showed that with only a single dosage of pollution there was a proportionality between the added number of bacteria and the residual bacterial density remaining after various periods of incubation up to 72 hours. Similar results were obtained from continuous feeding experiments.

Following the chlorination of settled sewage Heukelekian (6) found there was a significant increase in the number of coliform organisms when the chlorinated sewage was diluted with unpolluted waters, i.e., stream or distilled water; the increase was greater in higher concentrations of sewage; the increase was greater when sewage was chlorinated to a higher residual than with lower residuals; and that there was no material increase in coliform organisms when chlorinated sewage was diluted with sea water.

Weiss (12) demonstrated that turbidities usually encountered in natural waters affected the E. coli. content by adsorption of the bacteria on the particulate matter. The degree of adsorption was characteristic of the origin and particle size of the silt. Adsorption to silt particles increased the rate of sedimentation of bacterial cells. Diluted sea water increased the rate of flocculation of silts.

It has been shown by Tubiash [10] that nitrate and nitrite ions in very small amounts exert an inhibitory effect on the production of gas from lactose broth by members of the coliform group. Anaerogenic levels range from 30 p.p.m. to 60 p.p.m. nitrate-or nitrite-nitrogen against representative strains of E. coli. A. aerogenes was able to produce gas from lactose broth in the presence of slightly greater nitrogen levels, whereas A. cloacae appeared more sensitive to the presence of these ions. Nitrates in drinking water at levels which occur not infrequently may be responsible for bacteriologically false-negative reports for the presence of the coliform group.

Clark et al [3] have shown that examinations of water by procedures using the membrane filter gave results comparable to the coliform M.P.N. of the "confirmed test" and to the "agar plate count" of "Standard Methods." The filtration method had a marked advantage over the standard plate count method for the enumeration of bacteria in samples of low bacterial density. The method was commended for the counting of bacteria in relatively clear waters with high or low bacterial densities and in turbid waters of high bacterial populations. Using a modified Endo broth the membrane filter procedure was advantageous because large samples could be tested in a minimum time of 16 to 18 hours and with a marked reduction in labor, equipment, space and material. A method for the rapid isolation of S. typhosa from large samples was also described.

The results of bacteriological analysis of water supplies for farms and creameries in Wales has been discussed by Franklin and George (5). There was a close correlation between the presumptive coliform content and the presence of milk-souring organisms, though 30 per cent of the samples containing no coliform organisms contained other types of milk-souring bacteria. Nearly all samples of water containing large numbers of coliform caused an active fermentation of milk. This indicated that the coliform test could be used as an indication of the suitability of a water supply for dairy purposes.

Laurell and Lufstrom (7) have described an epidemiological investigation of epidemic hepatitis in a small community of Sweden in 1945 to 1947. Fifty-six cases of the disease occurred. Good evidence was obtained that the water supply was the source of infection.

When sewage from three tuberculosis sanatoria was examined by Vahlne (11), virulent tubercle bacilli could be recovered regularly by guinea pig inoculation. The sewage from one of the sanatoria was treated in contact beds, from the other two, only in sedimentation tanks. In rivers receiving sewage from these sanatoria virulent tubercle bacteria could be found as far down-stream as 1.24 miles from the sewage outfall.

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STREAM POLLUTION - Biology

The effects of dissolved and suspended matter pollution on aquatic life, especially fish, was discussed by Huet (35) who recognized that various types of pollution often stimulated the growth of the characteristic organisms. According to Liebmann (44) the presence or absence of many species of the biological community is used to classify water into four major quality groups. The effects of pollution by sewage, industrial wastes and silt on the productivity and recreational uses of streams was discussed by Cooksey (16). Industrial wastes innocuous to humans may affect adversely the biology of the stream.

Doudoroff (23) stated that the biological studies of industrial pollution should be directed toward reliable estimation and understanding of the effect of pollutants on important aquatic resources. An evaluation of fish habitats and their productivity was recommended. Toxicity bioassays were considered important in order to predict the effects of industrial pollution and to determine remedial measures.

A clean stream was defined by Czensny (17) as one in which the normal fish fauna are able to live and breed, where the composition of fish food organisms has not been changed or diminished in number, and nothing interferes with fishing operations. The effects of different types of pollution on the fish, on fish food organisms and on fisheries were discussed. It was concluded that the absence of fish "typical" of the stream can indicate pollution.

Doudoroff and committee [24] outlined a comprehensive bioassay procedure for the evaluation of the toxicity of industrial wastes to fish. The care and feeding of test fish, the design of experiments and methods of evaluating the tests were given in detail. Bioassay procedures were outlined by Daugherty [18] and LeClerc [42] to measure the toxicity of wastes to fish. Wuhrman and Woker [85] studied the variability of the reactions of test fish in toxic solutions in order to determine valid bioassay procedures. At least five and preferably ten fish per assay were recommended.

Huet [36] discussed reactions of fish to toxicants, methods for determining toxicity and factors affecting the bioassay tests. The toxicity of some common substances, such as mineral and organic acids, water of high alkalinity, metals, concrete, sodium and calcium chlorides, ammonia, chlorine, arsenic, artificial fertilizers, products from the distillation of tar and petroleum, nicotine, natural resins, pyrethrum, saponin, picrotoxin, and substances secreted by molluscs were given.

Woker and Wuhrmann [82] tested the sensitivity of several fish species to ammonia, HCN and phenol. Minnows were more sensitive to ammonia than trout; on the other hand, trout were more sensitive to phenol than minnows. It was concluded that fish accustomed to highly oxygenated waters should not be regarded as always more sensitive to toxicants than fish accustomed to oxygen poor waters. Each species of fish has its own toxicity spectrum.

Kasai [38] studied the animal communities in the acid streams of Japan. The principal characteristic of these rivers is the paucity of animals, especially aquatic insects. The changes in the composition of the animal communities at the confluence of acid streams with normal streams was described. Arnold and Royce [6] investigated the effect on bottom fauna and fish from the disposal at sea of about 3,000 tons per day of a solution of sulphuric acid and ferrous sulphate. Preliminary observations showed that the waste mixed with, and was buffered by, the upper fifty feet of sea water. Surveys of the dumping area and of a control area failed to show significant changes in the animal populations of the two areas.

The survival of trout in KCN was studied [2]. The survival period was affected by the size of the fish and the conditions under which they had been kept before the tests.

Pulley [58] studied the effects of aluminum chloride on various marine organisms. It was found that: 44 p.p.m. of $AlCl_3$ in sea water did not kill adult fish, shrimp or oysters; 88 p.p.m. killed young redfish quickly and other species more slowly; 132 p.p.m. killed all fish in a few days and most fish in a few hours, while 176 p.p.m. killed all fish in a few hours. Oysters are more resistant than fish.

Scheuring [63] found that sodium sulfate, a waste product of the staple-fibre industry was not extremely toxic at concentrations of 0.5 per cent or more to most water organisms. Green and blue-green algae flourished in concentrations up to 1.5 per cent.

Podubsky and Stedronsky [56] found that copper, brass and zinc metal were decreasingly toxic to pike fry and spawn. Iron was harmless. Copper, zinc, brass, iron and nickel metal were decreasingly toxic to fish and river crabs [57,55]. Aluminum was toxic in waters low in calcium. Zinc or tin plated metal was slightly toxic while stainless steel, nickel plate, chromium plate and lead plate were non-toxic. Plankton and insect larvae were also used as test organisms.

Ogi [52] treated artificially fertilized eggs of Plecoglossus with dilute solutions of lithium chloride and produced several types of monstrosities. Lithium was found to have a deleterious effect on all types of body tissues. Lallier [39] found that immersing the eggs of amphibia in dilute solutions of lithium chloride slowed their development and significantly reduced the oxygen consumption of the embryos. Smith [67] found that fish lived in domestic tap water that contained an average of 0.1 p.p.m. of copper.

LeClerc and Devlaminck [43] tested the toxicity to fish of various substances found in gas work wastes. The minimum amounts of the inorganic acids, bases, and their salts as well as hemoglobin poisons and organics causing death within six hours were determined. The in vivo and post-mortem symptoms caused by each substance were described. KCN was the most toxic of the substances examined. Chemicals used in oil well drilling were classified by Daugherty [19] into non-toxic substances, low toxicity substances and toxic materials. Caustic soda, oil well cement, Tannex, and white lime were fatal to many test animals in concentrations ranging from 70-450 p.p.m.

Wurhmann and Woker [86] correlated concentration and reaction time in solutions of pure phenol for several fish species. The curve obtained follows a hyperbolic function and may be expressed by a linear relation. Jones [37] found that solutions of phenol and ortho- and para-cresol were highly toxic to fish and have an effect on their nervous system, causing them to lose their sense of balance and capability of coordinated movement. At low concentrations, minnows appeared to have little discrimination between the toxicants and the water. At higher concentrations, the fish avoided the toxic solutions. Trahms [75] found that trout and perch died very quickly in a 0.16 per cent solution of phenol diluted with tap water. Carp could stand 1.9 per cent without injury. All dead fish had a bad smell and taste. Sorenson [69] conducted experiments to determine the toxicity of an acid waste containing phenol as well as potassium, sodium and iron. At a waste concentration of 250-500 p.p.m., daphnia were killed in 10-12 days, whereas at a concentration of 750 p.p.m. the daphnia were killed in four days.

In 1937, the life of Lake Orta was destroyed by Cuprammonium salts [7]. Only a few algae and rotifers survived. The situation has not changed in 20 years of continued pollution. The lake water has a high ammonia, nitrate and chloride content.

The wastes from sulfate pulping mills contain organic compounds such as resin acids and volatile compounds which are toxic to fish according to Essen [25]. Improved pulp washing techniques and recovery of black liquor have reduced this type of pollution. Halmi [32] claimed that pulping wastes harm streams by depleting the dissolved oxygen and ultimately forming hydrogen sulfide and methane. Experiments were conducted to determine

the toxicity of alkaline effluents that had been treated in different ways. It was found that fertilized fish eggs were more resistant than newly hatched fry and that the latter were more resistant than older developmental stages of the same species. When the sulfite effluent was treated with a sufficient amount of base, its poisonous effect was considerably reduced. The poisonous resins were almost entirely removed from the effluent by creating a foam. By mixing the effluents from sulfate and sulfite factories, the poisonous effects of each waste were reduced so that the eggs and fry lived in the undiluted mixed effluent and indicated that dual disposal might eliminate the harmful effects of pulping wastes.

Williams et al (81) determined the toxicity of sulfite waste liquors to four species of salmon. The tests were carried out in brackish water and toxic effects were demonstrated in the presence of adequate dissolved oxygen. Sulfur dioxide was claimed to be responsible for part of the observed toxicity.

Trichloroethylene, a cleaning and degreasing agent, was found to be toxic to fish and to the organisms responsible for the biological purification of sewage (8). The trichloroethylene was detected by the color formed with pyridine. Ganapati and Alikunhi (31) observed heavy mortalities among breeding fish caused by an alkaline waste water containing free chlorine and a high content of suspended solids. The toxicity was due mainly to the free chlorine. Gambusia were able to survive in pond water containing 1 p.p.m. residual chlorine.

A comparison of the sensitivity of bacteria and fish to toxic chemicals was made by Stone et al [72]. It was found that although fish and bacteria tolerate a similar range of pH values, fish are more sensitive than bacteria to most toxic substances.

Pyridylmercuric acetate, a slime control and fish disease control agent, showed a specific toxicity to rainbow trout [83,61,30,59]. It was found that 5 p.p.m. pyridylmercuric acetate was toxic to rainbow trout and not to brook trout. Lundgren [47] found that 90 per cent of a slime control agent, phenylmercuric acetate, added to process water, remained with the pulp. The mill effluent contained less than 0.01 p.p.m. which is the maximum concentration tolerated by fish.

Young and Nicholson [89] and Warrick [80] reported extensive fish kills in streams tributary to the Tennessee River following heavy rains in an area where fields of cotton had been repeatedly sprayed heavily with toxaphene, gamma isomer of benzene hexachloride, DDT and aldrin. Not only were fish killed but many species of fish food organisms were depleted. Muller [50] found that 190-250 p.p.m. of DDT (Gesarol) was lethal to fish and fish food organisms. DDT dusts were less dangerous than emulsions or oil solution. Schwarz [65] studied the toxic effects of DDT and difluoro-diphenyl-trichlorethane to fish and frogs by examining the responses of the poisoned animals to electrical stimuli.

Daugherty and Garrett [21] determined the 24-hour median tolerance limit (TL_m) for several substances discharged as wastes into ocean waters. Tests with Lagodon rhomboides gave the following 24-hour TL_m: hydrocyanic acid, 0.069 p.p.m.; lactonitrile, 0.215 p.p.m.; acrylonitrile, 24.5 p.p.m.; cyanobutadiene, 71.5 p.p.m.; acetaldehyde, 70.0 p.p.m. The toxicity of

nicotine to fish was evident in dilutions of 1:50,000 and 1:300,000 and was greater in alkaline than acid solutions (87).

The number of salmon in Swedish streams decreased greatly as a result of industrial pollution, dam erection and overfishing (84). As a part of a major study, tests were made to determine the toxic effect on predatory fish of slaked lime, lysol, ammonia, derris root, arsenic, picrotoxin and phenylmercuric acetate. In the concentrations used, arsenic and picrotoxin had little effect. Ammonia in concentrations of 17 to 136 p.p.m. killed eels, roach and trout in 15-16 minutes.

The Trent Fishery Board (2,76) investigated some major fish kills, several of which were due to preventable pollution. Many kills were due to the combined effect of pollution, high temperatures and low river flows. The 1949 drought in England (79) and Germany (77) had so reduced the oxygen content of the rivers that slightly increased amounts of pollution caused fish kills. Basu (10) reported on the ecology of fish ponds irrigated with sewage. Observations were made of the biological, chemical and physical changes of these ponds after the application of varying amounts of sewage.

Fish kills in two carp ponds were investigated (49). In one, algae growths were so prolific that light was excluded, dissolved oxygen was low and hydrogen sulfide was present. Fish of all ages died. In the other pond, a growth of Microcystis resulted in a high dissolved oxygen content and a pH of 9.55 at noon during the height of photosynthetic activity when young fish were killed. It was concluded that young fish could not

tolerate a high pH accompanied by a high organic content. LaRoze (41) described fish kills due to oxygen depletion caused by tannery waste pollution of a river.

Spraying carp ponds with copper sulfate at a rate of 8 kg. per hectare per summer season improved carp production and controlled gill rot (12).

Landa and Komers (40) described the purification of wastes containing phenols, napthenic and napthenates and studied the toxic effect on fish of these substances. It was claimed that petroleum refinery wastes kill fish primarily by depleting the dissolved oxygen content.

Schmassmann (64) studied the toxicity to fish of synthetic detergents. It appeared that both a fatty acid and a pyridine detergent had adverse effects. The latter affected respiration and the nervous system. Twenty p.p.m. of a detergent killed fish in less than 12 hours. Degens et al (22) tested the toxicity of several detergents to Daphnia, tadpoles and various species of fish. Five p.p.m. of all detergents tested were lethal to the organisms within 10-100 hours depending upon the organism and the detergent. Within limits, the animals could be acclimated to 9-36 p.p.m. of the detergent. Water plants did not appear to be affected by the detergents in concentrations up to 40 p.p.m.

Cicutoxin, an extract from the water hemlock, was found to be very toxic to fish (54).

Fry (29) reviewed the pertinent literature on the physiology and environmental relations of the trout. It was shown that a reduction of the oxygen tension to 50 per cent saturation produced a very unsuitable environment for trout even at quite low water temperatures. Speckled trout

will tolerate a pH range from 4.1 to 8.5 in nature, whereas laboratory trout have been acclimated to a pH of 3.7 to 10.7 without adverse effects.

Basu (9) kept fingerlings of Indian fish in a continuous supply of water containing low concentrations of oxygen. The fish were able to survive for over 24 hours in concentrations of about one p.p.m. but in these low concentrations they remained very quiet thus decreasing their need for oxygen.

Wallen (78) observed no unfavorable effects on 16 species of fish from turbidity until the turbidity approached 20,000 p.p.m. Most fish endured exposures to more than 100,000 p.p.m. turbidity for a week or longer, but these same fish died at a turbidity of 175,000 to 225,000 p.p.m.

Higgins (33) reviewed the literature on the effects of radiation to aquatic life and the levels of radioactivity in streams receiving atomic wastes. The General Electric Company (1), which operates the Hanford Works, is constructing an aquatic biology laboratory to determine the effect of reactor cooling water on fish and fish food organisms in the local streams.

Ross (60) reported cases of the poisoning of man and animals at Fanning Island by fish which were formerly eaten with no ill effects. The fish had been caught in areas where war material had been dumped. It was suggested that the plankton on which fish feed had been contaminated by poisons from deteriorating munitions. The toxic agent appeared to produce symptoms similar to those of aconitine. Brunner (14) found that fish may carry pathogenic bacteria externally and internally and present a hazard to fish handlers.

Tarzwell and Palmer [74] discussed the physical, chemical and ecological conditions affecting the growth of plankton and, hence, the water quality in the ever expanding use of reservoirs as sources of water supply. The value of biological studies, including algae and actinomycetes, to anticipate and alleviate nuisance conditions was emphasized.

Important clues regarding the origin and pollution of waters can be obtained by microscopic examination of the plankton and suspended matter in the water according to Stundl [73].

Stone and Abbott [71] found that the production of oxygen by algae in daylight generally exceeded the consumption of oxygen during the night but was dependent on the proportion of sewage pollution.

Flint [28] made a three year study of the algal flora and chemical quality of a London water reservoir which became stagnant when it was taken out of service. Lists of the species commonly occurring under conditions of high and low concentrations of nitrogen, phosphate and silica and with varying amounts of sunshine were given. Ludwig et al [46] found that algae in sewage converted nutrients into algal cell material which when discharged to streams serve as a food supply for fish and other animals. The algae in effluents from sewage ponds were biologically active and assisted in the purification of watercourses. Osterlind [53] discussed the physical and biological conditions that affect the growth of the alga Scenedesmus.

Studies [68] were made of the ecology of the tropical inshore waters high in phosphates and nitrites from sewage pollution near Miami, Florida. Many plankton were found at these and adjacent stations. Marine algae

found in the Mediterranean near Alexandria, Egypt were studied by Nasr and Aleem [51]. Bosshard [13] discussed the effect of hydrobiological changes since 1909 on the operation of water-treatment plants.

Abbott [5] noted that an algal growth appeared after one and a half months in a closed bottle filled with settled sewage despite the fact that much hydrogen sulfide was produced. The total sulfide was equivalent to 11.1 p.p.m. of sulphur. Fjerdingstad [26] found 124 species of plant microorganisms in stagnant ditch water containing from 0.2 to 45.0 p.p.m. hydrogen sulfide. The use of copper sulfate for algal control in water supplies was discussed [27,48].

The disappearance of large areas of marine eelgrass during the past 50 years from European and American shores was claimed responsible for a considerable depletion of fish and wildlife food [4]. Although the disappearance of the eelgrass was largely due to a fungus (Labrynthula) disease, the pollution from land and by oil from ships was considered to be a contributing factor.

Several cases of poisoning of livestock in South Africa [45] were believed caused by a blue-green alga (Mycrocystis toxica) growing abundantly in reservoirs. The methods used to isolate the toxin from the alga and the effects of the toxin on small animals were described. Smit [66] described symptoms observed in small animals treated with the toxin and the changes observed on post-mortem examination. Stewart et al [70] reported the loss of cattle in Ontario due to poisoning by a species of Microcystis in the drinking water. Wurtz [88] extracted an antiobiotic from Mycrocystis aeruginosa which had an antibacterial effect on

Clostridium bifermentans. Filtered pure cultures of Scenedesmus had the same effect on C. sporogenes. Daugherty [20] found oysters were killed in concentrations of sodium acid pyrophosphate of 500 p.p.m. or greater. . . .

Hoffman and Zakhary [34] found that temperature is a factor of primary importance in determining the effectiveness of copper sulfate when used as a molluscacide. Experiments over a range of 14°-26°C. showed a fifty-fold variation in toxicity with the snails dying most rapidly at the higher temperatures.

Billib [11] traced many intestinal diseases in Northwest Germany to shrimps from Cuxhaven. The shrimps were obtained from mudbanks in the estuary of the Elbe which are polluted by sewage from Cuxhaven and by waste waters from fish handling and processing plants.

The decrease in the fish population of the Staffelsee, Bavaria, [62] was claimed due indirectly to the clearing of a large woody area south of the lake which permitted acid water to drain into the lake and destroy the aquatic plants. The absence of aquatic plants caused the disappearance of clams.

Cercos [15] found that the toxic effects of fungocin, a detergent antibiotic of protein nature, on the fish, Gambusia affinis, follow a regular curve up to a dose of 500 ug per ml. Fungocin is also toxic to tadpoles. Bacilomycin has a toxic effect on fish.

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STREAM POLLUTION - B.O.D. and Chemistry

The mathematical analysis of B.O.D. data was discussed by Lee (9). The author believes the 20°C. "k" is usually 0.1 and attributes most of the other values reported are due to "failing to recognize the effect of the initial demand for oxygen." Williams (18) reported that the mean 20°C. "k" value of the Minneapolis-St. Paul sewage was 0.162 for raw sewage and 0.192 for primary settling tank effluent. Progressively lower "k" values were observed in river samples collected from just below the plant outfall to farther downstream. Murdock(12) commented on the progress of studies by the "National Council for Stream Improvement" aimed at stream improvement through supplying air to receiving waters to permit the stream to more quickly recover from its pollutional load. Murdock (15) also summarized the effect of low stream temperatures in retarding self purification. Bollens (2) discussed the relationship between micro-biological metabolism and the satisfaction of B.O.D.

It was reported by Patterson (16) that the Carney River in Oklahoma has suffered increased pollution by oil brines until it contains more than 200 p.p.m. of chloride and has a salty bitter taste. Textile wastes, according to Murdock (14), are objectionable in streams because of their color, sulfite and metallic salt content resulting in highly colored alkaline waters for several miles downstream below their discharge. Churchill (5) pointed out that paper and pulp mill wastes rendered many miles of otherwise clean streams, dark and objectionable in color. It required 40 c.f.s. per ton of paperboard produced, plus considerable natural

purification, to reduce the color to that considered normal for streams in the area.

Phenol concentrations should not exceed 2 p.p.b. after initial dilution in streams for protection against tastes in water supplies according to DeLaporte [6] . This limit in streams would require treatment of effluents to reduce phenol content to 20 p.p.b. before discharge. Ettinger et al [7] studied the persistence of phenols and cresols in polluted waters under anaerobic conditions and reported removals of 1 p.p.m. of phenol and ortho-cresol at room temperature after 14 and 7 days, respectively. At 40C. the same quantity of these phenolics required 33 and 9 days, respectively, for removal anaerobically. Serial additions indicated acclimatization with more rapid removal but atypical runs were also reported in which the phenol was not completely used up.

According to Ettinger and Ruchhoft [8] , phenolic materials in polluted water fall into three groups as determined by the results of step-wise partial chlorination:

(1) Phenolic materials which have their taste-producing intensity enormously increased by partial chlorination until a maximum taste intensity is reached, after which further addition of chlorine results in progressive decrease of the taste intensity until the "chlor phenol" taste can no longer be detected. This group includes phenol, the cresols and o-chlorophenol.

(2) Phenolic materials which have their taste intensity progressively decreased by chlorination. This group includes 1-napthol, and 2, 4,dichlorophenol.

(3) Phenolic materials of limited intensity as taste-producing substances in small concentrations. This group includes 4,chlorophenol and all of the phenols studied which had three or more positions chlorine substituted.

Bulicek [4] reported that phenolic wastes contribute a large part of the stream pollution problem caused by industrial wastes in Czechoslovakia.

Moore and Ruchhoft [11] reported that the chemical oxygen consumed and B.O.D. tests are two different parameters indicating biological and chemical oxygen requirements which have no a priori intrinsic relationship. In streams receiving domestic sewage the O.C./B.O.D. ratio increases as the stream becomes biologically stabilized.

The effect of cyanide on the B.O.D. reaction in polluted waters was found to be quite variable by Ludzack et al [10]. Special microbic growths were able to oxidize organic matter in the presence of cyanide after an initial lag period that depends upon the cyanide concentration and the stage of seed development. Little reduction of cyanide was accomplished during a normal 5-day incubation, except in waters with a previous history of cyanide pollution. In the river waters studied, there was a proportionally greater effect of small doses of cyanide on the inhibition of B.O.D. As long as the cyanide content was not appreciably

greater than 6 p.p.m. increase in cyanide concentration showed relatively small additional increments of inhibition. As much as 50 per cent or more of the organic matter as in the control was stabilized at 20°C. in the presence of cyanide concentrations up to 6 p.p.m. within a 10-day incubation period. Skopintsev (17) followed the biological oxidation in river waters over a period of 180 days at 16°-20°C. He found the reaction unimolecular with a reaction constant of 0.01-0.06. He concluded that incubation periods of 5 to 10 days give only relative values on the oxidation of unstable compounds and that incubation periods of 50 days or more are required for the oxidation of stable compounds.

Albright (1) described the use of sodium nitrate to reduce offensive odors in a badly polluted stream. In this case, oxygen as sodium nitrate equivalent to 10 to 20 per cent of the 5-day B.O.D. was added to the river. Murdock (13) discussed the control of H_2S odors in the Androscoggin River by the addition of sodium nitrate. The quantity of nitrate to be added was determined on the basis of the water temperature, sulfite liquor load, dissolved oxygen and methylene blue stability. During 44 days, 641.5 tons of sodium nitrate were used to reduce the H_2S to 0.01 p.p.m.

A study of the concentration and estimation of organic chemical compounds in the Ohio River was reported by Braus et al (3). These workers reported 9.3 to 32 parts per billion of organics in the river water using a carbon filter extraction technique. The lowest concentration of these extracts that could be detected by the threshold odor test ranged from 3 to 25 p.p.b. It was realized that the quantitative extracts reported might

be subject to considerable error due to deficiencies in the carbon used, in variation in filtration rates and metering errors. The technique seems promising for special stream and industrial waste studies.

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STREAM POLLUTION - Standards, Surveys and Studies

The New York State Water Pollution Board adopted standards of water quality for seven classes of surface water based on the "best usage of waters" (21). Similarly, standards of water quality for round water and tidal water were adopted. The standards vary from Class AA waters which are not polluted and may require only disinfection for "best usage" as drinking water through different degrees of pollution and best usage to Class F when the "best usage" is sewage or industrial wastes disposal and the standard of water quality is such as to prevent a public nuisance. Intermediate classes consider the suitability of the water for sources of drinking water, bathing, fishing, agricultural uses, industrial uses, etc.

The fresh water "standards" have been condensed and tabulated by Hess (18) for ease of comparison. The principal features of the standards according to Hess are: (a) disposal of wastes is one recognized best usage for waters in New York State, (b) any class of waters can be used for purposes listed in all lower classes provided the specifications of that class are not violated, (c) no numerical limits are given for a large proportion of the specifications, (d) the limits for phenol compounds are related to water use for drinking and food preparation, rather than effects on fish life, (e) the limit for dissolved oxygen in Class D is related to fish survival rather than to industrial or agricultural usages, and (f) the system indicates that toxic, deleterious, colored, or heated liquids may be limited in Class A - D by best usage other than those specified. In discussing the similarity of the New York standard for

Class A with the International Joint Commission objectives, it is pointed out that the State standards are limited to receiving waters while the objectives include both effluent and receiving waters.

The application of the Pennsylvania's standards for control of pollution in Class A, B, and C streams was discussed by Daniels (13). The standards of effluent quality discharging into a stream are based on "percentage removal" required for the treatment of domestic sewage. The treatment required of an industrial waste is interpreted as that treatment necessary to produce an effluent comparable to that required for domestic sewage treatment. This eliminates the need of extensive studies on each industrial waste. The objectives of boundary water quality of the International Joint Commission were given and discussed by Berry (11). The objectives of adequate control of pollution include both treatment plant effluent and surface water quality.

A number of stream pollution survey or study programs have been reported during 1951. The Ohio River Valley Water Sanitation Commission gave a comprehensive report of its activities in 1950 and 1951 (1,2). The 1950 final report consisted of an extensive water quality survey of the Ohio River. The survey involved a 12-day program of simultaneous sampling at 36 sampling stations located along a 963-mile stretch of the river. Hydrometric data and the results of bacteriological, sanitary, chemical, and mineral determinations are presented in the detail. The 1951 report discussed the projects undertaken, progress made in pollution abatement, and pollution abatement objectives.

An intensive survey of a 130-mile stretch of the Wabash River (Indiana-Illinois) was reported (3). This survey was sponsored by the Ohio River Valley Water Sanitation Commission and was accomplished through the combined efforts of eight cooperating organizations. More than 1,000 samples were collected in the 25 day sampling program. Results of the survey permitted determination of the requirements for waste treatment facilities at Terre Haute and Vincennes, Indiana.

The Public Health Service (6) reported on a cooperative water pollution survey of the South Platte River Basin in Colorado, Nebraska, Wyoming. The Public Health Service, the Bureau of Reclamation, the Colorado State Department of Public Health, and the City and County of Denver, Colorado cooperated in this survey. The report includes a description of the basin, a discussion of the economic development of water resources, the pollution damages to water resources, the benefits which may accrue as a result of pollution abatement. Also considered were pollution prevention measures in effect, pollution abatement needs and recommendations relative to water pollution control programs. Laboratory, hydrometric, and other data which were collected during the survey are presented in tables and diagrams.

A water pollution survey of the St. Johns River at Jacksonville, Florida was described by Sheddan (24). Pollution made the stream unsatisfactory for bathing, but did not prevent the use of the stream as a source for domestic water supply, nor did it present a problem concerning fish and wildlife conservation or shellfish culture. A summary of information concerning water quality, stream flows and sources of pollution for each

of Florida's major rivers was presented by Phelps and Barry [23]. The statistical probability of low stream flows of specified magnitude was considered.

A three year study to determine the limitations on the ability of Baltimore Harbor to accept waste discharges without undergoing objectionable changes was reviewed by Garland [17]. The study included the sources and types of waste loadings, the chemical and bacteriological water quality and hydrographic investigations. A study of the shore waters of Biarritz, France was reported by Souchard, Andrieu and Darmendrail [25]. Sea currents and dilution prevented undue contamination of nearby beaches, but the authors concluded that the major purifying action was from the antibiotic power of sea water.

A survey of Port Gardner Bay and Snohomish River Estuary, made during the fall of 1949 by the Washington Pollution Control Commission, was reported by Eldridge and Orlob [16]. A pollutional barrier caused by waste discharged by two sulfite pulp mills and the City of Everett, Washington was demonstrated in the estuary of the south branch of the river. Fish kills have occurred and river frontage and beach areas have been adversely affected by the pollution.

Ketchum [19] presented a method of calculating the effective dilution of fresh water flowing into an estuary and a means of determining the ratio of fresh to salt water at any location in the estuary if the physical characteristics of the latter, the rate of river flow and the position of the tides are known. The results of the study represent a refinement over the tidal prism method for the analysis of dilution problems in tidal estuaries.

A study of the Conestoga River, Pennsylvania, to determine if organisms living in a stream could serve as indices of stream conditions, particularly as related to domestic and industrial wastes pollution, was described by Patrick [22]. The results of the study indicate that a great many species, none represented by a great number of individuals, will be present in a healthy stream, but that pollution will eliminate less tolerant species and permit greater abundance of the more resistant ones. A brief description of a biodynamic stream survey of this type, made prior to the construction of a nylon intermediates plant by the DuPont Company, is given by Murdock [20].

Dougan and Bell [15] discussed the manufacturing processes of a synthetic rubber plant and described its waste materials and methods of waste treatment. The study included the results of a survey of a 20-mile stretch of the stream which receives the plant's effluent. Bergamin and Correa [8] described the condition of a small stream which receives the wastes of a tannery, the wastes of five textile works, and the sewage of a town.

The International Joint Commission studies of 1946-1948 on the pollution of boundary waters was reported [5]. A survey of industrial wastes in the Lake Huron-Lake Erie section of the boundary waters from the International Joint Commission studies was reported by Berry, Black and Oeming [12]. The report includes a comprehensive discussion of the industrial wastes program and the progress which has been made in pollution control. Two other articles dealing with the International Joint Commission

study of the domestic and industrial waste pollution of boundary waters were also presented by Berry [9,10].

A water quality survey of Lake Erie by the Division of Water, Ohio Department of Natural Resources was reported [7]. Highly polluted tributary streams appeared to be the worst offenders in the pollution of the lake. Determinations of coliform organisms, B.O.D., and dissolved solids were included in the survey. A majority of the bathing beaches sampled were found to be polluted beyond tolerated public health limits. Dewitt and White [14] presented a preliminary report on a study to determine the characteristics of pollution of large, relatively still, bodies of water by the entrance of contaminated tributary streams. The results of dissolved oxygen, B.O.D. and coliform organisms determinations for the study were presented.

The results of determinations of discharge, temperature, color, dissolved and suspended solids, and selected mineral and chemical constituents of the waters of many surface streams in the United States, were published [4]. Data for the publication were collected during the period October 1945 to September 1946. Additional information concerning oxygen consumed values, pH, and concentrations of additional chemical constituents was given for a number of the streams.

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ANALYTICAL METHODS

Gellman and Heukelekian [13] discussed the limitations of the "Standard Dilution" method for the determination of B.O.D. as compared to manometric methods. Factors concerned with the manometric determination such as CO_2 absorption, nitrification, agitation and sample volume were studied. They concluded (a) that the highest oxidation rates obtainable with the Sierp and Warburg apparati are 520 and 360 p.p.m. per hour, respectively, (b) that the reproducibility is equal to that obtained by the "Standard Dilution" method, and (c) that oxygen demand measurements may be 20 per cent higher for organic compounds and 14 per cent higher for domestic sewage by the direct method. Ludwig et al [26] also studied extensively the direct method for determining B.O.D. by means of the Warburg apparatus. They present a simplified procedure for use in making the necessary calculations. These authors believe that the method offers advantages over the "Standard Dilution" method but that the technique must be simplified before it can be used for routine determinations.

Chakravarti and Som [6] compared the 5-day B.O.D. values of a vegetable waste, an activated sludge plant effluent and several septic tank effluents with those obtained by chemical oxidation. The chemical method used was oxidation with dichromate in a H_2SO_4-H_3PO_4 mixture at 140°-145°C. The excess dichromate was titrated iodometrically. The oxygen consumed values multiplied by .68 were slightly higher than the 5-day B.O.D. in about one-half the cases and considerably higher in the remainder due to the presence of cellulosic material.

Moore and Ruchhoft [37] pointed out that B.O.D. and oxygen consumed are two distinct parameters that are not interchangeable. In domestic sewage from which the settleable solids have been removed and by using certain experimental conditions for determining the oxygen consumed, a close correlation was obtained between these two parameters. In streams receiving domestic sewage the O.C./B.O.D. ratio increases with increasing biological stabilization. The authors also stress the fact that where a given industrial waste is fairly constant in composition and contains no toxic compounds, that a satisfactory correlation can be obtained between the oxygen consumed and the biochemical oxygen demand.

Continued interest was shown in the determination of oxygen consumed of organic materials. Pirogova [45] modified the permanganate method of Skopintzev (J. Applied Chem. U.S.S.R. 7, 1294 (1934)) by pretreating the the sample with alkali and boiling for 10 minutes followed by neutralization before oxidizing with permanganate. Knox and Pask [21] used 0.1N dichromate in a H_2SO_4 solution for the determination of diethyl ether and ethyl alcohol in blood samples. The sample was adsorbed on filter paper suspended above the oxidizing solution. The digestion was 3-4 hours at 37°C. An accuracy of $\pm$ 2 per cent is claimed. It is obvious that the method would be applicable only to highly volatile compounds.

Medalia [32] in determining the presence of trace organic material in water relied on the reaction between ferrous iron and hydrogen peroxide. This reaction initiates a chain reaction in which the organic compounds react with the molecular oxygen present. The results obtained are higher

in most cases than with permanganate but lower than those obtained with dichromate. Shaw [52] determined the oxygen consumed values of coke plant wastes by using chromic acid as the oxidizing reagent. The reaction was carried out in the presence of H_2SO_4 and H_3PO_4. The mixture was heated for five minutes on a steam bath and the excess chromic acid reduced with an excess of ferrous iron. The excess of the latter was then determined by titration with dichromate. Chlorides are not attacked.

Riehl [47] reviewed the various methods for determining oxygen consumed with chief emphasis on the dichromate reflux method of Moore. Pepinsky et al [44] described a rapid dichromate procedure for the oxidation of organic wastes. The reaction was carried out in the presence of phosphoric and sulfuric acids and the heating time was such that a temperature of 165° is reached in six minutes. The excess dichromate was determined iodometrically. Chloride was oxidized quantitatively and silver sulfate could be used as a catalyst providing the starch was used as an outside indicator. If the heating time was extended, then breakdown of the dichromate resulted and high oxygen consumed values are obtained.

Moore et al [36] made a statistical comparison of the oxygen consumed results obtained by three dichromate modifications, the "Standard Permanganate" method and an iodic acid method. Pure organic compounds, as well as typical industrial wastes, were used in the study. With some materials as many as a hundred determinations were made. The use of silver sulfate as a catalyst increased the percentage oxidation with most samples. This was especially true with straight chain acids and alcohols. The results obtained in this study indicate that the Moore dichromate method (Anal. Chem. 21, 953 (1949)) would give the most reproducible results with a wide

variety of samples. With the iodic acid method and in those methods in which the excess dichromate was determined iodometrically, the use of silver sulfate as a catalyst is precluded.

Verbestel et al [57] made a critical study of the various methods for the determination of dissolved oxygen in concentrations around 0.01 p.p.m. It is pointed out that limitations in the iodometric titration make the Winkler method unsuitable for determining trace amounts of dissolved oxygen. Of the colorimetric methods that have been proposed, it was stated that the o-tolidine method was the most suitable.

Splittgerber et al [54] and Meyer and Brack [34] also investigated the determination of dissolved oxygen by means of o-tolidine. The latter authors stated that from 0.02 to 15 mg./liter of dissolved oxygen can be determined in clean waters. Iron interference was eliminated by the addition of $Na_4P_2O_7$. Both papers gave detailed directions for the determination of dissolved oxygen by this method.

Wickert [59] found that the toluidine method was satisfactory if the iron content was not over 0.02 mg./liter. If iron in excess of this amount was present, low dissolved oxygen values were obtained. This error can be avoided if thiocyanate is used in conjunction with the toluidine method. The oxygen equivalent of the ferrous to ferric iron was added to the dissolved oxygen as determined by the regular toluidine method.

Rand and Heukelekian [46] compared the dissolved oxygen results by the Winkler and polarographic methods on industrial wastes. The waste was first boiled to remove any dissolved oxygen and then known increments

were added. It was claimed that the polarographic method permitted reasonably accurate determination of the dissolved oxygen. A detailed procedure is given for the determination. Stone and Eichelberger (55) described an apparatus for the preparation of water of a known oxygen content as well as that used in the titration of dissolved oxygen in an atmosphere of CO_2. This latter consisted of a 1.0 ml. titration burette, graduated to 0.01 ml. and is provided with a reagent reservoir and a 3-way pressure stopcock. The method consisted in adding the water sample to an excess of chromous chloride, the excess Cr^{++} was then oxidized with an oxygen-free solution of KIO_3. Potassium iodide was added and the liberated I_2 titrated with chromous chloride in the presence of starch indicator. The presence of 10 p.p.m. of nitrite resulted in an increase of 0.7 per cent in the dissolved oxygen values.

Marsh (31) developed a portable polarograph using a rotating platinum electrode for determining dissolved oxygen in oil-field brines. An accuracy of $\pm$ 5 per cent is claimed for the instrument. It was possible to detect differences of 0.02 mg./liter of dissolved oxygen even though the absolute error may be greater than this. Moggio and Burland (35) proposed a method for the standardization of standard thiosulfate solution by using saturated solutions of dissolved oxygen. The method is rapid and simple and an accuracy is claimed equal to that obtained with primary standards. Corrections must be made for barometric pressure and temperature.

The determination of nitrogen in its various forms continued to interest many research workers during the year. Thompson and Morrison (56) made a detailed study of the determination of organic nitrogen by means of Nessler's reagent. The variables studied by these workers included correct Nessler reagent, presence of organic material, sulfate concentration, alkalinity of Nesslerized sample, temperature during Nesslerization, effect of time of reading after Nesslerization, and the presence of metals which will react with iodine. They found that all of these factors affected the final color formed and the amount of turbidity present in the Nesslerized sample. Wiebke (60) determined small amounts of ammonia in the presence of hydrazine by precipitating the latter with $CuSO_4$ in a sulfuric acid solution. The copper complex was allowed to settle at about 5°C. and filtered off. The ammonia was distilled into standard acid and methyl purple used as an indicator.

Hayazu (14) used dry air instead of steam in expelling the ammonia in his micro-Kjeldahl determination. White and Long (58) carried out the micro-Kjeldahl digestion in sealed tubes in the presence of H_2SO_4 and mercuric oxide. After reaching a temperature of 470°C. the digestion was continued for 15 minutes. The method was found to be quite effective in the determination of various types of organic nitrogen which might be encountered in industrial wastes. Marquex and Alliota (30) in the Kjeldahl nitrogen determination added $K_2S_2O_8$ and H_2O_2 in addition to the sulfuric acid. After carbonization of the organic matter had taken place the mixture was boiled and a second portion of the $K_2S_2O_8$ and H_2O_2 added. Boiling was continued for 20-30 minutes after which the mixture was made alkaline and

and the NH_3 distilled off. Jenkins [18] studied the effect of urea hydrolysis on the determination of NH_3 in sewage. He found that urea was completely hydrolyzed to NH_3 by incubation for two hours at 33-35°C. in the presence of five urease tablets per liter, or by standing at room temperature for 24 hours without the addition of urease. Secondary and final tank effluents, on the other hand, showed no increase in NH_3 content either with or without the addition of urease, due no doubt to the prior hydrolysis. He concluded that fresh sewage should be allowed to stand 24 hours before the NH_3 is determined unless it is desirable to know the urea content. Jenkins [20] also determined organic nitrogen in sewage, effluents and river waters by boiling the sample with caustic and Devarda allow prior to digestion with sulfuric acid and distillation. Buljan [4] used a method for the determination of NH_3 in sea water based on its action on a hypobromite in an alkaline solution. In an acid solution the NH_3 will not react. Therefore, hypobromite was added in equal quantities to two samples of sea water, one of which was acidified. The excess hypobromite is estimated volumetrically by the addition of a Bordeaux B dye solution. Jenkins [19] determined nitrite plus nitrate by heating the residue from the NH_3 determination with Devarda alloy and distilling into N/140 H_2SO_4.

Due to the increased interest in stream pollution by industry a wide variety of problems have arisen in the analysis of industrial wastes. An evaluation of all of the analytical procedures applicable to specific wastes that have been published in the past year would be a major problem. However, some methods applicable to a wide variety of industrial wastes are noteworthy.

The phenolic group of compounds have received considerable attention due to their taste and odor producing characteristics in water supplies. Ettinger and Kroner [8] discussed in detail the necessary steps involved in their determination in industrial wastes. These steps may involve one or more distillations, alkaline evaporation, solvent extraction, and precipitation for the removal of interfering materials followed by a colorimetric determination by either the Gibbs or the 4-aminoantipyrine method. Ettinger et al[9] evaluated the various factors involved in the determination of phenol by the 4-aminoantipyrine method. The factors studied included effect of pH, temperature, order of addition of reagents, and reagent concentration, etc. It was found that greater sensitivity could be obtained by extracting the color with chloroform. The method is sensitive to about 2 p.p.b. when applied to surface waters. Dannis [7] also investigated the 4-aminoantipyrine method for the determination of phenols in coke plant wastes. He studied some of the factors involved and concluded that the method could frequently be used without preliminary distillation. The time involved in this case was about 10 minutes. Shaw[51] also studied the determination of phenol in coke plant wastes and for phenol concentrations above 30 p.p.m. used a bromination procedure. The 4-aminoantipyrine method was used for low concentrations of phenols and a sensitivity of about 20 p.p.b. was claimed. In this case, however, the color formed was read in the aqueous phase since no extraction procedure was used. The factors controlling the reaction must be rigidly adhered to according to Shaw. The application of infrared spectroscopy to the determination of phenolic compounds was made by Simard et al [53] . Bromination was used as the first

step with subsequent extraction of the bromphenols with CCl_4. The optical density of the extract was measured at 2.84 microns. Less than 10 p.p.b. of phenol can be determined.

Simard et al[53] determined oil on the same CCl_4 extract used for the determination of phenolic compounds. The optical density was measured at about 3.4 microns. A mixture of cetane, iso-octane and benzene was used as a reference standard. It is claimed the method is sensitive to 0.1 p.p.m. of oil in a water sample. Musanti[38] in the determination of oil in refinery waste waters extracted serially a three liter sample (acidified with HCl) with nitration grade benzene. The solvent was removed by careful distillation and the oil residue weighed.

Braus et al[3] outlined a procedure for the isolation of organic compounds in water, which no doubt could also be applied to the study of various industrial wastes. The method consisted essentially of passing a large volume of the water through an activated carbon filter which adsorbs the organic compounds present in the water. The carbon was extracted with ether or chloroform. The residue from this extract was broken down by micro-organic methods into various groups, such as phenolic, neutral, acidic, amphoteric and basic. These groups can be further separated into the organic compounds present by microtechniques.

In many cases it is advantageous to know the color intensity of an industrial waste that is to be discharged to a receiving stream. Rudolfs and Hanlon[49] have proposed a spectrophotometric method for determining the absorption characteristics of waste samples. These characteristics are

related to the tristimulus values and a standard illuminant source. Results are expressed in dominant wave length (millimicrons), luminance (per cent) and purity (per cent). The transmission characteristics are determined at pH 7.6 and also at the pH of the waste sample. These same authors (50) also proposed a more simplified method using tristimulus light filters combined with a specific light source and photoelectric cell for the determination of the color of industrial wastes. The results obtained by this method are approximately the same as those obtained by the spectrophotometric method.

One of the most toxic constituents of industrial wastes, particularly, by-product coke and metal finishing waste, is the cyanide radical. Many methods have been proposed for its determination and research is still being conducted. Kruse and Mellon (23) reviewed the determination of cyanide by the pyridine-pyrazolone method and claim greater sensitivity and color stability for it than by the pyridine-benzidine method, although no experimental data were given. Nusbaum and Skupeko (40) studied the determination of cyanide in sewage and polluted waters by the pyridine-benzidine method. The cyanogen-halide was formed by the addition of bromine to the sample acidified with H_3PO_4. The excess Br was destroyed with sodium arsenite. Butyl alcohol was used as the extractant for the cyanogen-bromide and the color developed in the alcohol layer on the addition of the pyridine-benzidine reagent. Free cyanide was determined by this method in the range of 0.02 to 0.50 p.p.m. with little interference. Thiocyanates could also be determined by the proposed method. Will (61) made

a comparison of various methods for the determination of cyanide. The methods studied (no experimental data are given) included the Liebig, phenolphthalein, pyridine-benzidine and pyrazolone procedures.

The determination of metallic ions in industrial wastes has assumed increased importance due to the toxic effect upon the biological equilibrium of the receiving stream. Butts and Mellon [5] studied the polarographic determination of such ions as Cu, Fe, Cr, Cd, Ni, and Zn in industrial wastes. Horvai [17] determined copper colorimetrically with the sodium salt of tetrabromophenolphthalein. The sensitivity of the method was not mentioned and it was necessary to remove both iron and chromium prior to the analysis. Fassett et al [10] were able to determine from 0.06 to 15 micrograms of Cr with an accuracy of 5 per cent by the diphenylcabazide reaction by varying the absorption cell length and the final volume.

With the increased use of fission products the possibility of stream pollution by radioactive wastes has increased. Many methods have been published for the determination of radioactive elements. Fields and Pyle [11] discussed the determination of U and I^{131} (an alpha and beta emitter, respectively) as representative of radioactive materials that could be found in streams. Both a fluorometric and a radiochemical method were discussed for the determination of U. It is pointed out that the procedure for the determination of beta emitters presents many problems and corrections must be applied to the count obtained in order to arrive at the absolute disintegration rate. Fletcher [12] studied the factors involved in the "direct" fluorometric determination of uranium in the range

of 0.005 to 0.08 micrograms of U. Reproducible results could be obtained by fusing at 650°C. for 25 minutes using a carbonate-fluoride flux. Kolthoff and Johnson [22] determined UO_2, Th, Zr, and Sn (IV) by titrating with m-nitrophenylarsonic acid amperometrically.

Chlorination is finding increased usefulness in the fields of sewage and industrial waste treatment and is no longer confined to the field of water treatment practice. Nusbaum and Meyerson [39] made a study of five methods for the determination of chlorine in checking the chlorine-demand of sewage samples. They found excellent agreement between the p-aminodimethylaniline and acid starch-iodide methods. The neutral O. T. method gave comparable values with these two methods but caused difficulty in reading. The acid O. T. and neutral starch-iodide method showed no correlation with the above three methods. Lur'e and Nikolaeva [27] studied various methods for the determination of free chlorine and chloramine in water. The methyl orange method was recommended for determining the chlorine-demand of water. By the proper control of the iodide ion concentration and pH, Marks et al [29] were able to quantitatively determine hypochlorous acid and mono and dichloramines by amperometric titration. The hypochlorous acid was titrated at neutral pH with phenylarsineoxide, a small quantity of KI was added and the mono-chloramine also titrated at neutral pH. The pH was then lowered to 4, more KI added and the dichloramine titrated. Williams [62] also determined free chlorine and mono and dichloramines by amperometric titration. The results obtained amperometrically were compared with those obtained with the Palin colorimetric method. Nusbaum and Skupeko [41] used the well known

cyanogen-halide plus pyridine-benzidine reaction for the determination of free and combined chlorine. The free chlorine was destroyed by arsenite and the combined chlorine determined by the same reaction. From 0.055 to 1.4 p.p.m. of available chlorine can be determined by the method. The authors claim the method is particularly suitable for use in sewage chlorination. Aitken and Mercer (1) described a photometric method for the determination of free and combined chlorine by buffered o-tolidine at a pH of 7.0.

Even though the Versenate method for hardness has been widely accepted it is still being subjected to considerable research. The effects of interfering ions on the reaction, as well as the proper indicator and buffer concentrations, were reported in several papers (25,15,43,42).

Mestayer (33) used a volumetric method for the determination of sulfate in water samples. The sulfate was precipitated with an excess of 0.01 N $BaCl_2$, the mixture evaporated to dryness and then taken up in 50 per cent alcohol. The excess $BaCl_2$ was determined by titration with standard $(NH_4)_2SO_4$ using as indicator a mixture of Victoria Blue, barium, rhodizonate and ignited talc.

Mannelli (28) and his co-workers have studied the use of adsorption indicators in the argentometric determination of halides and SCN^-. The ones which seem to be particularly useful are Bordeaux Red and Orange II. With these, both I^- and Cl^- can be determined in the same solution.

Rose (48) described a photo extinction apparatus for the determination of turbidity in water samples. It is claimed the apparatus will give absolute results and that no calibration is required.

With increased use of fluoridation of water supplies the determination of fluoride is important. Ballczo and Kaufmann [2] reviewed the fluoride determination and proposed the distillation of fluoride from $HClO_4$ in the presence of Fe-Si. The fluoride was titrated with $Th(NO_3)_4$ using alizarin sulfonate indicator to which methylene blue had been added. As little as 3 gamma of F can be determined. Horton et al [16] used a spectrophotometric method for the determination of fluoride in the range 0 to 50 micrograms. The method is dependent on the bleaching action of fluoride on the red color produced when "thoron" reagent is added to a standard $Th(NO_3)_4$ solution.

In some sections of the United States the occurrence of selenium in water supplies is of sanitary significance. Lambert et al [24] proposed a procedure which with suitable modifications can determine from 0.1 to 5.0 p.p.m. of Se. The reaction is based on the action of selenious acid on the iodide ion to form free iodine. The liberated iodine can be determined spectrophotometrically at 315 millimicrons or the starch-iodide blue color can be formed and measured at 615 millimicrons.

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RADIOACTIVE WASTES

The Problem

In a preliminary report [30] on the industrial utilization of fission product (a waste from the operation of nuclear reactors) the Stanford Research Institute stated that "The U. S. Atomic Energy Commission produces vast quantities---as by-products of plutonium production." Most of the products were stored underground in large concrete vaults and the Atomic Energy Commission had asked the Stanford group to study potential industrial applications. If industry shows enough interest the charges for one to 1000 curies per pound for gross fission products may be $0.10 to $1.00 per curie or the charge for highly refined and separated isotopes having up to 30,000 curies per pound may be $1.00 to $100.00 per curie. The radiation characteristics and yield of fifteen of the radioactive isotopes in fission product were tabulated. The potential uses for killing organisms, controlling biological reproduction, artificial aging of foods, causing chemical catalytical effects, polymerization, oxidation, and halogenation were briefly discussed. "More than enough fission products are in storage and after processing could supply potential users with ten-thousand and even hundred-thousand curie quantities."

The rapid growth of the industry and present sources of wastes were discussed by Murdock [63], Straub [83] and Emlet [25]. "Isotopes" [3], a new publication containing information relative to

sources, characteristics and availability of radioactive elements, was approved for publication April 11, 1951.

The problem of radioactive waste disposal was reviewed [8,31,32,76,82,93]. Wolman and Gorman [93] concluded that the future growth of the atomic energy industry may well hinge on its ability to find increasingly effective and reasonably economical methods of disposal of its hazardous waste products.

The areas of existing and proposed Atomic Energy Commission facilities were located geographically and Atomic Energy Commission sponsored programs of research and development in waste disposal and environmental sanitation at a dozen centers were outlined by Gorman [31,32], while the total activities of the Atomic Energy program were outlined elsewhere [1].

The decay of gross fission product from the simultaneous slow fission of uranium^{238} and the relative abundance of radioactive elements at any given time after fission from 10 seconds to 100 years were recalculated by Hunter and Ballou [40] from the most recent information available. The decay rate is extremely rapid at first and much slower as the product ages. For example, for every 1000 disintegrations per minute (dpm) at zero time, there remains only one dpm after five hours; for every 1000 dpm at five hours there remains one dpm after 100 days; and for every 1000 dpm at 100 days, there remains one dpm after 100 years. During the cycle of growth and decay any one particular radioactive isotope usually assumes greater relative prominence for a given age until the growth of daughter isotopes overshadows it in prominence. Thus, with age, there is a succession

of radioactive elements of different chemical behavior. In the age span of several months to 100 years, columbium, cerium, cesium, strontium, yttrium, ruthenium, rhodium, barium, lanthanum, praseodymium and zironcium may be found.

The yield of fission product elements was somewhat different for the fission of thorium^{232} [91] according to radiochemical procedures similar to those developed by the Manhattan Project [14].

Radiation Safety

The International Commission on Radiological Protection adopted new radiation safety standards with more rigid criteria [43,44,45,46]. The maximum permissible surface exposure of the whole body to X-ray and gamma radiation was reduced by one-half to 0.5 r/week. This roughly corresponds to 0.3 r/week when measured in free air. In the case of high energy beta rays, the maximum permissible exposure to the surface of the body in any one week shall not be more than the equivalent energy of 1.5 r of gamma rays. In the case of fast neutrons the maximum permissible energy absorption should not be greater than one-tenth of that permitted for high energy gamma radiation.

The International Commission on Radiation Protection was not "in a position to make firm recommendations regarding the maximum permissible amounts of radioactive isotopes that may be taken into or retained in the body." However, the above radiation safety standard [46,44] was used to calculate a reasonable maximum permissible value for some of the more important radioactive isotopes. Values were calculated for both air and

liquid media. The values given for liquid media in micro-microcurie per milliliter are: 0.04 for radium^{226}, 0.8 for strontium^{90} plus yttrium^{90}, 1.5 for plutonium^{239}, 1.6 for strontium^{89}, 10 for cobalt^{60}, 30 for iodine^{131}, 200 for phosphorous^{32}, 800 for sodium^{24} and 400,000 for hydrogen^{3} (45,46).

The responsibilities and activities of the Subcommittee on Waste Disposal and Decontamination of the National Committee on Radiation Protection were reviewed by Jensen (47). The major isotopes shipped by the Atomic Energy Commission were considered of greatest importance. In order, these isotopes were: I^{131}, P^{32}, C^{14}, Fe^{55}, Fe^{59}, Au^{198}, Co^{60}, Na^{24} and K^{42}. Research should be directed to biological reconcentration studies and the movement of radioactive materials in soils.

Since it was not realistic to insist on dilution of radioactive waste in sewage to the level established as permissible in drinking water, the Subcommittee on Waste Disposal and Decontamination of the National Committee on Radiation Protection (88) reviewed the external and internal radiation hazard and recommended (a) raising the maximum permissible level to be discharged in sewers to a transient (maximum short-period) concentration of 100 uc of either isotope per liter of sewage, (b) that a single batch discharge of 10 millicuries be permitted, and (c) when a uniform discharge device is used, 100 millicuries of these isotopes may be discharged in any six hour daylight period into a system having an average dry weather flow of one million gallons. Since the dry weather flow during a six hour daylight period will usually exceed 25 per cent of the total daily flow, the average concentration of radioactive isotopes in the sewage from

uniform disposal devices will be less than the M.P.L. in drinking water of 0.1 uc of I^{131} per liter. Isotopic dilution was considered unnecessary. Restrictions on the total quantity of isotopes and advice on disposal practice were given in detail.

The Subcommittee also released a comprehensive booklet [87] on the maximum permissible levels of radioactive contamination of the skin, clothing, laboratory tools and glassware, work-tables, floors, etc.; precautions which should be taken in the safe handling of radioisotopes; emergency measures and procedures to be taken in case of laboratory accidents; and decontaminating methods. This booklet supplements the National Bureau of Standards Handbook No. 42 on the Safe Handling of Radioactive Isotopes.

Emergency Measures and Decontamination

A basic disaster plan [59] in the event of atomic attack can do much to save lives and protect non-contaminated personnel. This is a problem for the sanitary engineer. The general picture of types of radiation to be concerned with, their consequences, tolerance limits and a ten point check-off list evaluating the vulnerability of water supply systems to attack were described.

An effective disaster plan will require personnel familiar with the basic concepts of health physics [2], radiation monitoring [34], instrumentation and decontamination.

The practical aspects of emergency instruments concerning construction [24], testing and servicing [53], and calibration [58] of portable meters, ionization chambers, G-M tubes, proportional counting chambers, scintillation counters and associated electronic assemblies were reviewed.

Concerning surface decontamination, various types of surface from which radioactive material would be easily removed were studied [22,72,92]. According to Ross [72] smooth, non-porous and nonionic surfaces resistant to attack by acids, alkalies, solvents and heat should be employed and decontaminated with suitable detergents. The Naval Radiological Defense Laboratory [92] listed the advantages and disadvantages of various agents and techniques for decontaminating solid surfaces. The liberal use of water for preflushing and rinsing off acids, detergents and complexing agents made the methods particularly applicable for ship decontamination on the high seas where the disposal of contaminated wash and flush waters is of minor importance.

Concerning water contamination, an estimation of the 10-day and 30-day emergency levels of radioactivity in drinking water can be made with the relative inexpensive beta-gamma survey type meters used in area monitoring. Hursh, Zizzo and Dahl [42] presented techniques of procedure and calibration whereby each of the nine different survey meters tested were found satisfactory for detecting one to 90 microcuries of phosphorous^{32} per liter of water. One satisfactory technique consisted of pouring the water to a depth of one inch in a metal salve box of about four inches in diameter,

placing the sensitive part of a G-M tube at a fixed distance above the surface and observing the meter reading which had been previously calibrated in terms of microcuries of radioactivity per liter. Activities much less than one microcurie per liter can be estimated with survey meters if the water sample is first evaporated to dryness.

Lauderdale and Emmons [55,56] reported on an emergency water decontamination system. Two glass tube columns each 26 inches in length and having a capacity of approximately 225 ml. were filled with various absorbents and used to remove radioactivity from drinking water. The water was contaminated with 2.5 microcuries of 60-hour-old fission product per milliliter of Clinch River (Tennessee) tap water, adjusted to pH 7.5, and passed at rates up to 5.0 gals/min/ft^2 through successive beds of 15 inches of grade "0" steel wool, 8 inches of burnt clay, 3 inches of activated carbon and, finally, 26 inches of mixed bed anion-cation exchange resin. Using an effluent radioactivity of 0.1 microcurie per liter as a criterion of satisfactory performance it was found that:

(a) Twenty-six inches of mixed bed resin column used alone delivered three liters or 12 volumes before the effluent was unsatisfactory.

(b) The combination of 26 inches of mixed absorbents followed by 26 inches of mixed bed ion exchanger delivered 28 liters or 50 volumes before the effluent was unsatisfactory.

The activity was eluted separately from each absorbent and subjected to radiochemical analysis. It was found that the bulk of the ruthenium,

zirconium, strontium, cerium, cesium, niobium, tellurium and rare earths was removed by the steel wool. A relatively high fraction of the activity found in the burnt clay was cesium, strontium and rare earths. Most of the activity in the cation exchanger was strontium. Most of the activity in the anion exchanger was also strontium and some tellurium.

The ability of various exchange resins to remove the radioactivity of specific isotopes at concentrations of 1000 to 2000 cpm/ml. of various solutions was tested [49]. One of the purposes of these investigations was to develop a laboratory waste disposal unit consisting of a cartridge containing ion exchange resins.

A sample container was constructed [48] that permits the determination of the radioactivity of a liquid flowing through it. The unit consists of a G-M tube, mounted on a thin window face of the container.

Waste Treatment

The general application of various methods of waste treatment was discussed by Straub [83,84], Rodger [69,70], Newell and Christenson [64] and Ruchhoft [73]. Ion-exchange [6] and evaporation [62] methods were applied to the Knolls Atomic Power Laboratory wastes according to Ayres and McCullough, respectively. Carbonate precipitation and double sedimentation were used on the Harwell Laboratory wastes [4]. The laboratory waste treatment by sedimentation, dilution and dispersion at the Oak Ridge National Laboratory has been changed to that of concentration by evaporation and storage of residues according to Browder [10]. Following laboratory

research on chemical precipitation and biological treatment (activated sludge [75] and trickling filter) treatment of laundry waste [66] and process wastes [11] at Los Alamos, Newell and Christenson [65] reported plant operating results using dual chemical coagulation and sedimentation and then sand filtration for process wastes and high rate trickling filter treatment for laundry wastes. The process waste plutonium content was reduced from 200 to 25,000 cpm/liter of influent to 20 to 200 cpm/liter of filtered effluent.

Comprehensive data on the equipment, engineering and costs of radioactive waste disposal for the Argonne National Laboratories were reported by Rodgers and Fineman [71]. Radioactive gases are filtered through a fiber glass prefilter and a paper-asbestos final filter before discharging the decontaminated gases to the atmosphere. Stack gases from the incineration of combustibles first pass through three gas scrubbers before filtration. The liquid wastes are handled in one of three ways. Very active process wastes are neutralized with lime, mixed with Portland cement, hardened and shipped to a final storage area. Dilute wastes are collected in 1500 gallon glass-lined retention tanks and monitored. If the radioactivity is sufficiently low, it is discharged to an outfall sewer where it is diluted with 0.4 m.g.d. sanitary sewage. About 80 per cent of the liquid wastes may be discharged without treatment. If the level of radioactivity of the retention tank waste is greater than the maximum permissible for discharge it is pumped into a tank truck and hauled to holding tanks for evaporation or ion-exchange treatment. Scaling and foaming troubles in the evaporator have been eliminated by operating with an acidic feed. Wastes with

0.08 per cent solids were evaporated to 45 per cent solids. The beta activity of the condensate did not exceed 7×10^{-4} microcurie per liter. The evaporator bottoms are dried in a small stainless steel twin drum vacuum dryer and the residue packaged for shipment and final storage. Studies are in progress on the use of resin ion-exchangers for decontaminating some low level radioactive wastes rather than using the evaporation technique.

By simple evaporation, followed by deentrainment by means of a Fiberglass filter, a decontamination factor (influent concentration/effluent concentration) of at least 10 million was achieved for nonvolatile fission product waste solutions (57) from the Brookhaven National Laboratory.

The removal of radioactive contaminants was studied by Straub et al (85) in a 250 gallon-per-day experimental rapid sand filter plant and by means of jar tests. Tap water containing about 100 p.p.m. turbidity added as clay slurry was used as raw water and to this was added P^{32}, I^{131}, or simulated mixed fission product. The raw water was coagulated with 0.65 grains alum per gallon and 0.24 grains NaOH per gallon. Coagulation and sedimentation effected a removal of 85 per cent of P^{32} and 46 per cent mixed fission product. The overall removal by coagulation, sedimentation and sand filtration was 96 to 98 per cent for P^{32}, less than 0.4 per cent for I^{131}, and 70 to 73 per cent for mixed fission product. Jar tests indicated wide variation of removals depending on kind and amounts of reagents used. Na_2CO_3 gave better removal for Y^{91} than NaOH. According to Lauderdale (54), and the Morton-Placak Group (26,86), phosphate and lime treatment for di- and tri-valent cations was quite effective at a pH greater than 11.3.

High removals of Ce^{144} and Sr^{89} were also obtained by passage through a column of burnt clay.

Laboratory studies on the fate of Na^{24} and Co^{60} as cations, of I^{131} and Br^{82} as halides and P^{32} as phosphate in sewage treatment by plain sedimentation, trickling filters and activated sludge, were reported by Belcher (7). The sewage was dosed with 0.5 to 50 uc isotopes per liter. Removals by plain sedimentation were small (one to five per cent) for all isotopes. Removal of I^{131}, Br^{82}, and Na^{24} by either trickling filters or activated sludge was also small (three to twenty per cent), whereas removal of P^{32} and Co^{60} by secondary treatment was greater (77 to 88 per cent). The dosing of a trickling filter with 100 uc P^{32} per liter of settled sewage for 24 hours failed to produce radiation effects that significantly altered the effluent indices - B.O.D., NH_3 N, NO_2-N, NO_3-N or oxygen absorbed values.

According to Grune and Eliassen (36) radioactive phosphorous when present in concentrations at or below 10 millicuries per liter exerted no significant effect on the first stage B.O.D. of sewage.

In laboratory studies at the Massachusetts Institute of Technology (23) simulated natural surface waters contaminated with I^{131}, P^{32} or Sr^{89} were treated by conventional water treatment processes using alum, ferric sulfate, lime-soda or lime-phosphate coagulants. The success of treatment depended on the raw water quality, the radioactive contaminant and the treatment process used. Over 99 per cent of the strontium was removed by the lime-soda softening or the phosphate-lime coagulation process.

After examining the amounts of iodine^{131} and phosphorous^{32} distributed to large centers of population in the United States, it was concluded by Ruchhoft and Feitelberg (74) that the probability seemed remote that any one hospital would discharge regularly as much as 200 millicuries of waste per day into the sewage of a large city. At this rate, the dilution needed to reduce the activity to safe limits was no major problem. A simple constant level, fixed orifice device for discharging liquid wastes to the sewer at a uniform rate, as suggested in the National Bureau of Standards Handbook No. 49 (88), was recommended for preventing excessive concentrations in the sewers. Calculations indicated that the hazard from sewage plant fertilizer would be quite remote. For example, the radioactivity of the filter cake fertilizer from digested sludge produced in a 12.5 m.g.d. primary sewage plant might be as much as 0.25 microcurie per kilogram only if the sewage flow received a daily discharge of 1000 millicuries of iodine^{131}.

Incineration and the Stack Gas Problem

A radioactive waste incinerator for contaminated combustibles was designed (5) following experimental work on the choice of scrubbing solution and the efficiency of various methods of dust collection.

Radioactive particulate matter in the stack gases from the incineration of contaminated combustible wastes was experimentally removed by Schauer (79). High efficiency of decontamination was obtained by introducing the gas stream into a steam exhauster. Condensing water droplets increased the size of particulate matter which then could be removed by conventional gas scrubbing equipment.

It was found that, in the incineration of combustible laboratory wastes containing radioisotopes, the fluxing of the radioactive residues with molten NaOH was a safe means of disposal (13).

A comprehensive two-volume report (9) on the experimental studies conducted with three types of glass fiber for decontaminating radioactive aerosols was released.

Biological Effects

A survey was made of the radioactivity of fish collected from fresh water which received radioactive industrial wastes (51). Fish collections were made from White Oak Lake and three embayments of the TVA Watts Bar Reservoir on the Clinch River, 0.2, 2.5 and 8 miles below White Oak Dam. Samples of flesh, bone and scales were assayed for radioactivity (50). In general, the bone was more radioactive than the flesh by a factor of 7 to 10 and the scales were more radioactive than the flesh by a factor of 10 to 20 on a unit weight basis at each collection point. The flesh of the White Oak Lake fish was roughly 10 times as radioactive as the flesh of the radioactive specimens just below the dam, 40 times as radioactive as the flesh of the radioactive speciments found 2.5 miles downstream and 50 times as radioactive as the flesh of the radioactive specimens found 8 miles downstream. However, only the most radioactive specimens at the lower collection stations representing less than ten per cent of the total catch were assayed. Radiochemical analysis indicated that, of the radioactivity in the flesh, 96.8 per cent was due to cesium^{137}, 1.7 per cent was due to strontium^{89} and strontium^{90} and 1.5 per cent was due to yttrium^{90}.

The bone and scale radioactivity was largely strontium^{90} and its daughter yttrium^{90}. The human consumption of 2.5 to 10 ounces of flesh from fish in the most radioactive water (White Oak Lake) contained sufficient strontium radioactivity to exceed the daily "maximum permissible" dosage. The health hazard from the ingestion of bone or the solution of strontium from bone when fish is prepared for the table was not considered.

From a laboratory investigation of the uptake of I^{131} by heterogeneous bacterial slimes, Talboys (89) found there was little tendency for I^{131} as the iodide to concentrate in the slimes of sewer drains. It was concluded that the resultant hazard to maintenance workers who may contact the contaminated slimes would be very low.

Two groups of rats drank only nuclear reactor cooling water effluent, adjusted to either 3 or 300 micro-microcuries of radioactivity per milliliter for periods of 200 to 500 days (38). Growth rate of the experimental rats was not affected by the radioactivity, and no histological changes were observed. In the group which drank the greater concentration, the blood and kidneys usually had the highest specific activity of about 20 micro-microcuries of Na^{24} and P^{32} per gram. It was concluded that the hazard to mammals drinking Columbia River water containing diluted cooling water was negligible if the diet provided all the essential elements.

A study of the urinary elimination of radioactivity following an incident in which an individual became contaminated with strontium^{90} was reported (17).

Natural (Background) Radioactivity

The various components of background radiation and the various naturally occurring radioactive substances were described [16] in a semiquantitative manner in connection with problems of radioactive waste disposal, etc.

Water samples (source and tap) were collected from 18 cities in the western part of the United States and measured for radium content [41]. The radium content of the source water ranged from about 0.03 to 2.0 micro-microcuries per liter and for the tap water from about 0.03 to 0.3 micro-microcuries per liter.

In an investigation of the radium content of common foods, the radium content of fresh, dried and commercial powdered milk has been determined to be between one and four micro-microcuries per kilogram of dried milk solids [78], or 0.1 to 0.033 as much as reported by Burkser et al. (Biochem. Z. 211, 323 (1929)).

Amounts of radioactivity reported in hot springs and spas throughout the world have been assembled on a geographical basis [61].

Radioactive clouds were investigated by airplane [29]. The activity was reported in equivalents of radon. The maximum concentration found on June 11, 1950 was 0.01 uuc/m^3 at elevation 2000 meters. On January 13, 1951, it was 0.03 uuc/m^3 at elevation 4000 meters. On February 3, 1951, it was 0.15 uuc/m^3 at elevation 4100 meters. The activity had a half life of 20 to 50 hours. On February 7, 1951, the following precipitation, the atmosphere was essentially free of activity. The origin of active clouds (either from atomic explosion or by derivation

from its products) the fall-out factor and condensation nuclei were considered.

Analytical Methods

The radiochemical studies of the fission products by the plutonium project of the Manhattan District, consisting of 336 papers, were edited by Charles D. Coryell and Nathan Sugarman [15] and published as a National Nuclear Energy Series, Division IV, Volume 9. The table of contents of this three-book set may be found in Nuclear Science Abstracts, Volume 5, No. 9, page F, May 15, 1951.

Detection methods available for the investigation of radiocolloids, the theory of their formation, nature and applications were reviewed [81]. The results obtained by various investigators were summarized concerning the radiocolloidal behavior of Po, Bi, Pb, Th, Y, Zr, Nb, La, Np, Pu, Pa, Mg, Sc, Sn, Ti, Ce, Be, and Ba.

The radiochemistry of separating I^{131} and uranium from waste solution and the problems of absolute counting of alpha or beta radioactivity were considered in detail [27].

In determining radioactive iodine in fluid or tissue [68], the sample was treated with $KMnO_4$ and concentrated H_2SO_4 and distilled. The iodine was collected in lithium arsenite solution and an aliquot evaporated for counting with an end-window counter.

A simple process has been devised for the recovery of I^{131} from the urine of treated patients [19]. The process consists of $AgNO_3$ precipitation followed by bromination of the residue to iodate, pH adjustment, and final purification by distillation if desired.

Chemical techniques for sample preparation, construction and operation of an ionization chamber and electronic equipment were described by Hudgens et al [39] for the determination of as little as 10^{-14} grams of radium per gram of sample from a measurement of the radon which was allowed to grow into partial or total equilibrium with the radium.

A method for determining polonium in biological samples was described [77]. The method consists of wet oxidation and coprecipitation with tellurium. The polonium is then separated from tellurium and deposited on one side of a silver foil for counting. A recovery of 85 per cent and a sensitivity of one uuc from urine were reported.

In separating and estimating one of the more hazardous radioactive fission products, strontium, in water and urine, Mawson and Fischer [60] investigated the methods of Tompkins, Farabee and Khym (1949) and Kallmann (1948), and proposed a modification consisting of coprecipitation with calcium or other carriers as the oxalate (Sulkowitch reagent) at pH 4.0. Recoveries of 70 to 100 per cent were obtained from 750 ml. of urine to which had been added five to 12 counts per minute.

A relatively inexpensive apparatus for the simultaneous electroplating of up to 12 samples of material was described [21]. Various kinds of cathodes were listed and procedures for the determination of Cu, Ag, Zn, Hg, Fe, and Co were given.

A method was described [35] for the recovery of 37 year cesium^{137} from alkaline waste solutions by cocrystallization with potassium aluminum sulfate.

Paper chromatography was used to separate inorganic radioactive ions such as Fe from Co; Pb, Bi, and Po from each other; Mn from Zn and Na from K [28] . A Geiger tube was used to locate the chromatographed element and, by counting rate and decay, to determine the isotope and relative abundance.

Instrumentation

For monitoring the radioactivity in 500 ml. samples of sewage at the Brookhaven National Laboratory by the evaporation method, Cowan and Nehemias [18] concluded that the minimum detectable amount for P^{32} and C^{14} was 16 and 180 micro-microcuries per liter. Using 200 ml. of sewage to minimize self-absorption, the minimum detectable amount of polonium alpha activity was 3.0 micro-microcuries per liter.

A comparative study of the relative sensitivity of a thin mica end-window counter, a windowless G-M flow counter and a windowless proportional counter was made by Graf, Comar and Whitney [33] . Internal counters were found to be three to 30 times more sensitive than end-window counters depending on the energy of the ten beta emitting isotopes tested. Absorption data for 0-3 mg/cm^2 were presented for C^{14}, S^{35}, and Ca^{45}.

For efficient counting in a G-M end-window counting set, Cook et al [12] advise that the diameter of the sample on a tray be less than one-half the diameter of the end-window and placed a distance from the window either not exceeding 0.1 the diameter of the window or more than the diameter of the window.

The development of a simple automatic sample changer which can be used with windowless gas flow counter tubes for the measurement of alpha or soft beta particles was described [67].

A scintillation probe was developed [20] for counting alpha radioactivity and the self-absorption of beta radioactivity was evaluated by two different methods [80].

The alpha and beta activity of air was monitored continuously [52] by deposition of air dust on a strip of filter paper moving at the rate of about one inch per hour across an aperture through which air was pumped. The strip of paper, after collection of the dust, passed in front of one or more counters.

Taplin, Douglas and Sanchez [90] have improved their two-phase chloroform-dye indicator system for gamma radiation measurements by removing the alcohol preservative in the chloroform and thereby gaining sensitivity to within the 10 to 100 roentgen dosage range. By reducing the concentration of the dye and adjusting the pH closer to the yellow endpoint in alcohol-free systems, doses of one roentgen or less may be detected colorimetrically. The method is, however, wave length and temperature dependent.

Grune and Klevin [37] described the laboratory equipment and techniques used in studying the effect of up to 10 microcuries of P^{32} or I^{131} per milliliter of dilution water on the B.O.D. of sewage.

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